Sense of Shape

NASA takes step toward active wing-shape control with flights of new fiber-optic sensor

GRAHAM WARWICK/WASHINGTON

Hair-thin fiber-optic sensors under black sealant strips on wing surfaces of NASA's Ikhana UAV measure torsion in flight.

NASA/TONY LANDIS

NASA has demonstrated the ability to sense a wing's shape in flight and determine the stresses on its structure in real time, offering the possibility of improving aircraft efficiency and safety by actively controlling wing shape and redistributing loads.

The agency is wrapping up flight tests of the Fiber-Optic Wing Shape Sensor on its Ikhana unmanned aircraft, a modified General Atomics Predator B operated by NASA's Dryden Flight Research Center at Edwards AFB, Calif.

Six optical fibers attached to the upper surface of the Ikhana's wing provide more than 2,000 strain gauge measurements in real time. On each side, three 20-ft.-long fibers run from the wing root, aft of the leading edge, around the tip and back to the root, forward of the trailing edge. This allows the system to sense both bending and twisting of the wing, says Lance Richards, advanced structures and measurement group lead.

Weighing less than 2 lb., the hair-thin fibers are glued to the surface of the UAV's wing and covered with sealant, but they could be embedded within the composite structure on future aircraft. They would remain in the aircraft for its lifetime, gathering structural data.

To sense strain—deformation of the wing surface as it bends and twists under load—the system uses "fiber Bragg gratings." These are local changes in the refractive index of the optical fiber that reflect particular wavelengths of light. These gratings are located every centimeter along the fiber.

Using a tunable laser and special demodulation and processing schemes, the system is able to measure the strain at each of these gratings in real time. This allows deformations to be mapped across the wing and not just measured at discrete points using conventional strain gauges, says Richards. The data can then be used to calculate stress, bending displacement and torsion in real time, he says.

The Ikhana is also instrumented with calibrated strain gauges at 16 different locations on the wing to provide comparative data. Richards believes the NASA tests are the first time a real-time fiber-optic strain sensing system has been validated in flight. "We are pleased with how it has worked. There have been no issues," he says.

Seven dedicated test flights have been completed, and the system remains installed, gathering data, as NASA uses the Ikhana to image wildfires burning in California. While the test flights were around 2 hr., the fire missions last up to 8 hr., and Richards expects to have gathered some 30 hr. of sensor data by the time they are complete.

Richards says real-time knowledge of aircraft wing shape would be valuable. "The best application is probably long span, high flexure, high aspect-ratio wings with [tip] displacements measured in tens of feet," he says. "It would have avoided the Helios mishap," he adds, referring to disintegration of NASA's solar-powered flying-wing UAV when turbulence caused catastrophic pitch oscillations. "The operator had no idea where the wings were."

As a next step, NASA wants to demonstrate it can use the sensor in a system to adaptively control wing shape. "If we know the shape in real time we can feed that back into the control system to redistribute the loads," Richards says. That would allow weight to be removed from the structure by reducing the design margins now applied to ensure safety. "People are starting to call this capability 'fly-by-feel'," he says, as the spatial resolution provided by the fiber-optic sensor mimics biological systems.

Dryden is seeking funds to flight test active wing-shape control. This would use a next-generation version of the Aerostructures Test Wing flown under NASA's Boeing F-15B research testbed in 2001, Richards says. A combination of the fiber-optic sensors and advanced actuators would sense and change wing shape in flight to redistribute loads.